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1. Række Bd. 1—4.....	10 Kr.	Øre
2. — — 1—4 (= Bd. 5—8).....	10 -	8 Kr.
2. — pr. Bind.....	4 -	3 -
3. — Bd. 1—3 (= Bd. 9—11), pr. Bd.....	4 -	3 -
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— 13, Hefte 1 (udsolgt).....		
— 13, Hefte 2.....	1 -	
— 13 — 3.....	2 -	
— 14—16, pr. Bind.....	4 -	3 -
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¹⁾ Ved Henvendelse til Bestyrelsen.

Mortensen og Ostenfeld: „Alfabetisk Liste over danske Karplanter“ sendes portofrit i Indlandet til Medlemmer og Deltagere i den topografisk-botaniske Undersøgelse mod Indsendelse til Foreningen af 1 Kr., og til ikke-Medlemmer mod Indsendelse af 1 Kr. 50 Øre.

Descriptive Notes on the topography and vegetation of some localities visited by the excursion in Denmark arranged for the members of l'Association internationale des botanistes June 22nd—July 3rd 1913 edited by the Dansk Botanisk Forening, København 1913. — Faas hos Bestyrelsen, Pris 75 Øre.

1872), hvori han gennem Arkivstudier fører Bevis for, at der har været Fyrreskov paa denne Ø endnu i Slutningen af det 18de Aarhundrede.

Da Branth blev Præst i Vendsyssel, laa det nær, at han med sine levende naturhistoriske Interesser ogsaa kom til at sysle med de i flere Henseender meget interessante geologiske Forhold i denne Landsdel. Sandsynligvis har han ogsaa under sit Ophold i København hørt Forelæsninger i Geologi hos Forchhammer. I Tidsskr. f. pop. Fremst. af Naturvid. skrev han i 1876 en Afhandling: Hvorfra og hvorledes ere Stenene i det nordlige Jylland komne?, og i 1881 en anden om de geologiske Forhold i det nordlige Jylland. Begge Afhandlinger hviler, skønt publicerede i et populært Tidsskrift, helt igennem paa selvstændige Iagttagelser og har virkelig videnskabelig Værdi. I den første Afhandling lykkedes det ham, ved norske Geologers Hjælp, at føre et afgørende Bevis for, at Kristiania-Fjorden og dens Opland har leveret et stort Antal af de i Vendsyssel forekommende Sten. At hans Betragtninger over Isteorien ikke kan staa for Nutidens Kritik, kan man ikke undre sig over; men de Iagttagelser, hvorpaa de hviler, er skarpe og paalidelige. I den anden Afhandling behandler han mere spredtliggende Emner, bl. a. Istidsfænomener. Han tyder ganske rigtigt de ejendommelige Rimmer mellem Frederikshavn og Skagen som Stranddannelser. Han kommer her ind paa historiske Efterretninger om Fyrreskove i Vendsyssel, og han paaviser for første Gang Bøg i en Tørvemose i Vendsyssel (7—8 Fod dybt i Tørvn).

Under sin Virksomhed som Realskolebestyrer i Tønder udgav han en Lærebog i Naturlære, som er udkommet i otte Oplag og er blevet meget anvendt paa Seminarier og Højskoler. La Cour brugte den saaledes paa Askov i 40 Aar, hvad der turde være et talende Vidnesbyrd om dens Godhed, og der foreligger ogsaa fra anden Side Udtalelser om, at dens Forfatter ejede et sjældent pædagogisk Greb.

Branth's Virksomhed som Præst skal ikke omtales nærmere her. I sin Ungdom blev han stærkt paavirket af Søren Kierkegaard; han omgikkes i sin Studentertid meget »Grundtvigianere«, men som Præst sympatiserede han mere med Indre Mission. Han var i kirkelig som i andre Sager en ejendommelig, selvstændig Natur med udprægede Meninger, og dog var han meget liberal overfor anderledes tænkende. Han havde endog Samarbejde med Dissenterne, hvad der vakte Forargelse hos mange Præster herhjemme. I den kirkelige Presse skrev han jævnlig bl. a. om For-

holdet til Dissentere, om Søndagens Helligholdelse, om Bibelkritiken m. m.¹⁾).

Branth var saaledes meget virksom og interesseret baade paa det kirkelige og det videnskabelige Omraade, en Kombination, som vistnok er sjældnere nu end tidligere. Han følte sig samtidig som Præst og som Videnskabsmand, og han udtalte som gammel, at han havde haft meget Udbytte og Fornøjelse af at omgaas Naturforskere. Han deltog i Naturforsker møderne i Stockholm 1880 og i København 1892, og endnu i 1906 deltog han i Botanisk Forenings Ekspedition til Horsens-Egnen.

Men Branth's Interesse spændte over videre Felter. Intet menneskeligt var fremmed for hans livlige Aand. Selv i sin høje Alderdom bevarede han sine alsidige Interesser. I April i Fjor begyndte han at læse Cantú's Verdenshistorie, og i September havde han læst de 7 tykke Bind igennem Blad for Blad, vistnok ret enestaaende af en Mand paa 85 Aar. Og da Prof. Warming besøgte ham i samme Sommer, sad han og læste i Victor Cousin's *Histoire générale de la philosophie*.

At Branth's videnskabelige Arbejde værdsattes i Botanikernes Kreds, fik han et tydeligt Vidnesbyrd om derved, at han i Februar 1906 valgtes til Æresmedlem af Dansk Botanisk Forening. Det var ogsaa som Paaskønnelse af hans videnskabelige Virksomhed, at han i 1908 blev udnævnt til Ridder af Dannebrog. — Ved sine videnskabelige Arbejder har han sikret sig en hæderfuld Plads i den danske videnskabelige Litteratur.

Til ovenstaaende er benyttet Rostrup's Biografi i Biografisk Lexikon, en Nekrolog af Hakon Jørgensen i »Folkelæsning» for 15. Febr. 1918, Breve fra Branth til Rostrup og til Prof. Warming, velvilligst overladt mig af Frk. A. Rostrup og Prof. Warming, samt nogle Optegnelser af Enkefru Deichmann Branth. Omtalen af Branth's geologiske Arbejder støtter sig paa nogle Udtalelser, som Statsgeolog A. Jessen har været saa venlig at meddele mig. Med Hensyn til Deichmann Branth's botaniske Publikationer henvises til Warming's Den danske botaniske Litteratur (Bot. Tidsskr. 12. Bd. 1881) og Carl Christensen's Den danske botaniske Litteratur 1880—1911. 1913.

¹⁾ I det svenske religiøse Tidsskrift Facklan, hvortil han gennem en Aarrække leverede Bidrag, fremkom en Biografi af ham, da han blev 80 Aar.

Studies on the Production of Matter in Light- and Shadow-Plants.

By

P. Boysen Jensen.

1. Introduction.

A few years ago I carried out some investigations on the behaviour of forest trees to light (1910 p. 1). On that occasion I also made some experiments on the rate of the production of matter by young forest trees in relation to light (l. c. p. 56). During the summers 1911—1917 I made some further investigations on this question in other plants. The experiments were partly carried out in Vejen, Jylland, partly at Maglemose in Gribskov near Hillerød.

The problem especially to be elucidated through these investigations is how much organic matter certain plants of different types can produce per unit of time; the percent production of matter as I would call it. Let us begin with a definition. By the percent production of matter I mean the amount of dry matter produced in unit time, calculated in percent of the dry matter in the plant in question at the beginning of the experiment. When a plant with a content of 100 g dry matter produces in 24 hours 20 g dry matter, the daily percent production of matter is 20 %. In plantology similar conceptions are used. For instance GRAN (1908 p. 1) finds that about 20 % of the *Peridineae* in the sea divide during a night in Septb.; this figure 20 indicates the «speed of increase» for the organism in question.

In what follows we shall enquire how this percent production of matter can be estimated.

As may easily be seen, the question of the production of matter is very complicated, since all the factors acting on the plants influence also the intensity of the production of matter;

and the factors act not only separately, but also interfere with one another, so that all sorts of complications arise. However it will frequently be the case, that a single factor, such as light, temperature, the want of one or other substance in the soil, surpasses in importance all other factors, so that it is this factor, that either alone or chiefly determines the intensity of the production of matter (Liebig's law of minimum.) When such a limiting factor acts, the estimation of the production of matter will be very much easier.

The production of dry matter may be calculated as a difference between income and expense. The income is mainly composed of the organic matter produced by the CO_2 assimilation, the expense on the other hand can include a series of different accounts, such as the loss of matter by the respiration of leaves and stem, by the fall of leaves, by the production of seeds and so on. Though the question, as we said, is much complicated, it should be possible by studying intensively certain typical plants to calculate the sums of these different accounts separately, so that the following scheme can be made:

Expense.		Income.	
Loss of dry matter		Gain of dry matter	
by respiration {	of the leaves.	by CO_2 assimilation..	
	of the stem ..	ash	
	of the root ..		
by leaf fall		Sum of income	
by production of seeds		÷ Sum of loss	
Sum of loss...		organic matter produced...	

In other words it should be possible to make up a balance-sheet for the plant examined.

More exactly the estimations for any given day are to be carried out in the following manner.

At first the leaf area of the plant in question is determined. Further it is necessary to estimate the weight of the stem and root and the dry matter content of the plant. The dry matter content is calculated for a leaf area of 50 cm^2 .

Income. Besides varying according to the specific properties of the plant, the CO_2 assimilation is especially influenced by light and temperature. At first we must therefore measure the intensity of light and temperature during the several hours of a day, so that we can construct a curve, indicating the rate of change of these two factors during a day. After that the CO_2 assimilation of the plant should be measured in different inten-

sities of light and at different temperatures, and a curve indicating the influence of light on the CO_2 assimilation should be constructed. With the help of this curve and the curve for the variation of light it will be possible to calculate the gain of dry matter from the CO_2 assimilation per 50 cm^2 during a day.

Expense. Next the respiration of the leaves and the stem and root should be determined per 1 g and per hour; from this it will be possible to calculate the loss of dry matter through respiration during a day.

By subtraction of the loss from the gain, the net amount of dry matter produced during a day can be measured. By calculating it in percent of the dry matter of the plant we find the daily percent production of matter.

By calculations carried out in this manner it should be possible to gain an insight into the economic working of the plant. For instance such experiments would give information as to the difference which certainly is to be found between the intensities of CO_2 assimilation and respiration in different plants, and as to the significance of these differences for the economy of the plant; farther they might show a difference between plants with deciduous and those with evergreen leaves, between plants with a great mass of stem, and those without stem, between annual and perennial plants; in short such investigations may cast light on how the production of matter is regulated in any single case.

The following experiments are to be considered as a preliminary attempt so solve some of the problems alluded to above.

2. Methodic.

1. Estimation of the intensity of CO_2 assimilation. In order to determine the amount of CO_2 which plants in natural conditions assimilate it is necessary during the experiment to keep the plants in conditions resembling natural conditions as much as possible, and before all, the determinations should be carried out in an atmosphere with about the same CO_2 content as the air, viz 0.3 ‰ . Still in most experiments the plants have been enclosed in a flask in an atmosphere with $5\text{--}10 \text{ ‰}$ CO_2 , the tension being determined at the beginning and end of the experiment. Of course experiments made in this manner may give information on many points concerning the CO_2 assimilation; but for determining the amount of CO_2 assimilated under natural conditions, this method is not fitted, since the intensity of assimilation, as KREUSSLER and

several others have shown, is much accelerated with the rise of CO_2 content in the surrounding air.

The following investigations aim at determining the amount of the CO_2 assimilation at the same CO_2 tension as in atmospheric air.

WEBER (1879 p. 346) tried to measure this value by estimating the gain of dry matter in an experimentation time of 43—50 days. Every day he estimated the leaf area in m^2 and the time during which the plants were illuminated in hours. Hence the CO_2 assimilation per hour per 1 m^2 could be calculated.

SACHS (1884 p. 1) attempted to determine the intensity of assimilation by his weighing method. From leaves, which were as symmetrical as possible, he removed during the morning the one half, while he let the leaf stalks with the other half remain on the plant till the evening, when they also were cut off. From both the half-parts, known areas were cut out and the dry weights of the two samples were determined; the difference between them indicated the amount of the CO_2 assimilation during the day. In addition a correction for the migration of the synthesised carbohydrates had to be applied. By this method SACHS found, that the assimilation for *Helianthus annuus* was 1.88 g and for *Cucurbita Pepo* 1.5 g dry weight per m^2 per hour.

SACHS' method was sharply criticised by BROWN and ESCOMBE (1905 p. 29). They maintained, that the two half parts of a leaf may vary much in weight and that the area of the leaves may be altered during the time of the experiment. And it is to be remembered, that a small percentage error in determining the weight of the two samples of leaf pieces will cause a considerable error in the determination of the intensity of assimilation. According to investigations of THODAY (1910 p. 1 and 421) these errors can be avoided by suitable precaution.

The CO_2 assimilation can also be estimated from the intake of CO_2 . In these experiments the plant is placed in a stream of atmospheric air. The amount of air, which is drawn through the apparatus during a definite time and the CO_2 tension in the air is determined; hence the amount of the CO_2 , with which the plant is supplied during the experimentation time, may be calculated. When the air current has passed the plant, it is conducted through absorption-tubes, which take up the remaining CO_2 , and thus may be calculated how much CO_2 the plant has absorbed.

Such an apparatus was constructed by GILTAY (1898 p. 43). The air current was produced by the suction of two calibrated

MARIOTTE's flasks, of which the one could be filled, while the other was working. The air passed first through the plant receiver consisting of a glass bottle, through the bottom of which the plant could be introduced. From the receiver the air-current was passed through the absorption tubes. Of these the two first contained sulphuric acid to absorb the water, the two next were filled with 50 % KOH solution to absorb the CO_2 , and the two last with sulphuric acid to absorb the water vapour, which might be given off by the KOH tubes. The four last tubes were weighed before and after the experiment, and the difference between the two weighings gives the amount of CO_2 , that is not absorbed by the plant. At the same time an estimation of the CO_2 content in the air was made with a similar apparatus. A measured amount of atmospheric air was drawn through the apparatus; by weighing the absorption tubes the content of CO_2 per l. was determined. From these estimations the CO_2 taken up by the plant could be calculated as a difference between the CO_2 supplied and that remaining at the end.

GILTAY intended to compare the intensity of assimilation in Holland and Buitenzorg. He found, that *Helianthus* in Wageningen (Holland) assimilated 2.9 mg CO_2 in an hour per 50 cm^2 of the upper surf. + 50 cm^2 of the lower surface, and in Buitenzorg 4.0 mg CO_2 in the same time. It is to be noticed, that GILTAY's experiments gave lower results than those of SACHS.

Also BROWN and ESCOMBE (1905 p. 29) have made assimilation experiments in atmospheric air. They used an apparatus of construction similar to GILTAY's. The air current was produced by means of an aspirator.

The air passed first through the plant receiver, a wooden frame with sides of glass, with the leaf, which either was attached to the plant or cut off; in the latter case the leaf-stalk was placed in water. Afterwards the air current passed through an absorption tube with KOH, where the CO_2 that was not taken up by the leaf, was absorbed, and then through a gasometer, where the air was measured. The amount of the absorbed CO_2 was estimated by titration. Also here two experiments were carried out at the same time, since in addition the CO_2 content in the air was to be measured.

BROWN and ESCOMBE used a rather large leaf area, 300—800 cm^2 . Therefore they had also to use a very swift air current to supply the leaves with sufficient CO_2 , 200—400 l. per hour.

They experimented principally with *Helianthus annuus*, and

found that the intensity of the CO_2 assimilation in this plant is, on an average, 5.6—8.8 mg CO_2 per 100 cm^2 per hour, a similar value to that found by GILTAY.

I also made several assimilation experiments with an apparatus, described in my paper cited above. In this apparatus the air current was produced by the help of an aspirator. The air passed first through a WULFF's flask with KOH solution in order to absorb the CO_2 in the atmospheric air. In this flask a thistle-funnel was fitted, and the supply of air was regulated in such a manner, that the surface of the liquid in the thistle-funnel was constant; hence also the speed of the air current will be constant. Afterwards the air current passed through a conical flask with cotyledons of germinating peas, where the CO_2 content becomes greater than in atmospheric air; next through the leaf receiver and last through a tube with very dilute KOH solution, coloured with phenolphthalein. In order to determine the intensity of assimilation the time in which the KOH solution was decolorised, was measured. Also the CO_2 given off by the peas per hour was determined, and the intensity of assimilation could then be calculated.

Although the assimilation experiments with this apparatus are not carried out at the CO_2 content of atmospheric air, I have mentioned these experiments here, because they have given rise to the construction of an other and better apparatus, adapted to measure the CO_2 assimilation at the CO_2 tension of atmospheric air.

This apparatus (fig. 1) is based on the same principles as the above mentioned apparatus of GILTAY and BROWN and ESCOMBE: a current of atmospheric air is passed through the plant receiver with the assimilating leaf, and the CO_2 that is not taken up by the plant is absorbed by baryta solution and measured by titration. Besides the CO_2 content in the air is determined.

The air current is produced by two graduated vessels with side tubes, of 1—2 l. capacity (*A* and *B*), closed by india rubber stops with glass tubes. These tubes are fitted with india rubber tubes as the figure shows. One of the flasks (*A*) is filled with water and set say 110 cm above the other. The water will then run down into the second and drive the air in this flask out through the tubes *b* and *d*. At the same time air from the apparatus will be sucked into the flask *A* through the tubes *a* and *c*.

The tubes *a* and *b* are connected with a shifting apparatus *C*, so arranged that by shifting the flasks the intake of air always

occurs through the tube *c* and the expulsion of air through the tube *d*. This is attained by means of two Y pieces of glass and two twoways cocks, connected as the figure shows. When the vessels are shifted, the glass cocks are simultaneously turned through 180° and the air current will continue to go through the tube *c*.

The air current is passed first through the plant receiver (*E*). The form of the plant receiver varies much according to the leaves that are employed for the experiment. Conical flasks (vol. 50—100 cm³) are convenient for small plants with rosette

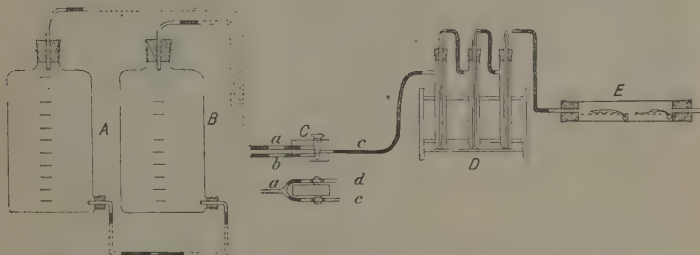


Fig. 1. Apparatus for estimation of CO₂ assimilation and respiration.

leaves, flat glassboxes, flat retorts or glass tubes for single leaves. Care should be taken that the quantity of air contained in the plant receiver is as small as possible. The leaves in the glass-boxes are fixed on a wire grating. The leaf stalk is placed in a small glass, made in the form of a retort from glass tubing with a diameter of 1 mm, to supply the leaf with water during the experiment. The width of the openings of the stomata may be estimated after the method of MOLISCH.

From the plant receiver the air current passes through the absorption apparatus (*D*)¹⁾, consisting of 3—4 test tubes (length 18 cm, diameter 12 mm), the form of which is shown in the fig. The air is conducted through capillary tubes, which are pressed against the bottom of the test tubes, so that the air passes through the absorbing liquid in very small bubbles.

In my first experiments the plant receiver was fitted in between the shifting apparatus and the absorption tubes and the air current was passed under pressure through the apparatus in the

¹⁾ Another absorption apparatus that also could be used in these experiments is described by WARBURG (1909).

opposite direction to that described above. This method can not be recommended.

The speed of the air current is regulated by a capillary glass tube, fitted in the india rubber tube connecting the flasks *A* and *B*.

The whole apparatus can easily be made portable, and the experiments can therefore be carried out anywhere.

It is clear, that the area of the assimilating leaf, the speed of the air current and the concentration of the baryta solution must correspond with one another. As mentioned already BROWN and ESCOMBE experimented with very large leaves with an area of 300—800 cm². Therefore they had to use a very quick air current. I prefer to use a leaf area varying from 4.4—100 cm² (upper + lower surface). In this case 2 l. air per hour, containing about 1 mg CO₂, is sufficient to supply the leaf with CO₂. The leaf area should vary with the intensity of assimilation. In intensive assimilation a small leaf area is used and vice versa. Generally the CO₂ tension in the air should not be diminished more than $\frac{1}{3}$ by the assimilation, for otherwise the assimilation also will be diminished too much.

The CO₂, that is not absorbed by the leaf, is absorbed by baryta solution and its amount determined by titration with HCl. The strenght of the two solutions is the same and can be varied from $\frac{n}{55} - \frac{n}{220}$. If the first concentration is used the experimentation time should be 2 hours, and the amount of the supplied air 4 l. 3 absorption tubes will be sufficient. It is best to have 2 apparatus working at the same time. In the latter case 3—4 absorption tubes should be used, and the experimentation time can be diminished to $\frac{1}{2}$ hour. The amount of air to be supplied is 1 l. In my experiments I have most frequently used $\frac{n}{110}$ solutions and an experimentation time of 1 hour.

The experiments are carried out in the following manner.

At the beginning the solutions are prepared, 500 cm³ of each and every day new solutions are made. The titration value of the baryta solution is estimated in the following manner. 10 cm³ of the baryta solution is filled into each of the absorption tubes and the stops with the glass tubes are set in. The stops are again taken out, and the content of the tubes is poured into the titration vessel and titrated with the HCl solution with phenolphthalein as indicator.

Now the CO₂ content of the air is to be determined. 10 cm³ baryta solution is filled into each of the absorption tubes; the

apparatus is set going, and at the moment when the bubbles are beginning to stream through the absorbing liquid, the water level in the vessels and the time is to be noticed. When a definite amount of air has passed through the apparatus, the cocks are turned 90° to stop the air current, and the baryta solution is poured into the titration vessel. The baryta solution is titrated with HCl solution, and from the difference between this value and the first titration value the amount of CO_2 in the air can be calculated. When the air current is passed under pressure through the apparatus (as was done in my first experiments) this value will often be too great, say 0.6 mg CO_2 per l. or more, since bacteria in the glass and india rubber tubes in spite of sterilisation frequently cause an evolution of CO_2 . This may often be an advantage, since when during assimilation the CO_2 content is diminished, it will lie near the natural content of atmospheric air.

The estimation of the CO_2 assimilation is carried out in a similar manner. The leaf is put in the plant receiver, the same amount of air as above is drawn through the apparatus, the baryta solution is titrated, and the difference between this and the former mentioned titration indicates the amount of the assimilated CO_2 . The leaf area (upper + lower surface) is determined by drawing the leaf on paper, cutting it out and weighing. Hence the CO_2 assimilation per hour and per 100 cm^2 surface ($= 50 \text{ cm}^2$ of the upper surface + 50 cm^2 of the lower surface) may be calculated.

An example will show how the calculations are carried out.

The experiment was carried out with *Rumex acetosella*, 2 leaves with a leaf area of 32 cm^2 (upper + lower surface).

30 cm^3 of the baryta solution corresponded with $30.2 \text{ cm}^3 \frac{n}{110} \text{ HCl}$. When 2 l. air were drawn through the apparatus, the titer of the baryta solution was $24.6 \text{ cm}^3 \frac{n}{110} \text{ HCl}$. $1 \text{ cm}^3 \frac{n}{110} \text{ HCl} = 0.2 \text{ mg } \text{CO}_2$. The amount of CO_2 in the air was consequently $0.56 \text{ mg } \text{CO}_2$ per l.

After the leaves was put in the apparatus, 2 l. air were passed through in 54 minutes, and the titer of the baryta solution was then found to be $27.0 \text{ cm}^3 \frac{n}{110} \text{ HCl}$. Hence it may be calculated that the amount of CO_2 assimilated in this time is $27.0 \div 24.6 = 2.4 \times 0.2 \text{ mg}$. The CO_2 assimilation per 100 cm^2 per hour is therefore

$$2.4 \times 0.2 \times \frac{60}{54} \times \frac{100}{32} = 1.7 \text{ mg. } \text{CO}_2.$$

Corrections. Every estimation is reduced to the CO_2 content of atmospheric air, viz. 0.55 mg per l. and to a temperature of 20° .

The first of these reductions is carried out in the manner described of BROWN and ESCOMBE (1905 p. 41). It is supposed that the CO_2 assimilation is proportional to the CO_2 content and that the assimilation takes place at a CO_2 content that is the mean between the CO_2 content of the air before and after it has passed the leaf. For instance, when the CO_2 assimilation is 4 mg per 100 cm^2 per hour and the mean CO_2 content is 0.44, the corrected value is $\frac{4 \times 0.55}{0.44} = 5 \text{ mg}$.

The influence of temperature on the CO_2 assimilation is investigated by MATTHAEI (1904 p. 47).¹⁾ In cherry-laurel the values for the different temperatures were as follows (mg CO_2 assimilated per 50 cm^2 per hour).

Temperature, $^\circ\text{C}$...	15	16	17	18	19	20	21	22	23	24	25	26	27
CO_2 assimil.	6,1	6,5	7,0	7,5	8,0	8,5	9,1	9,7	10,3	10,9	11,5	12,1	12,8

The shape of the assimilation curve is logarithmic; but it can be made linear if instead of using the normal degrees we use another scale obtained by reducing the value for the CO_2 assimilation for 20° , viz. 8.5, to 10 and the other values in the same manner. The values of this scale (we can call them physiological temperatures) are as follows:

Temperature, $^\circ\text{C}$.	15	16	17	18	19	20	21	22	23	24	25	26	27
Physiologic. Tp. ...	7,2	7,6	8,2	8,8	9,4	10	10,7	11,4	12,1	12,8	13,5	14,2	15,0

The physiological temperatures can be used by reducing the CO_2 assimilation from a definite temperature to 20°C . Supposing that we find a CO_2 assimilation of 4.4 mg at 18° , the value for 20° will be $\frac{4.4 \times 10}{8.8} = 5 \text{ mg}$ (supposing that the temperature influence the assimilation in the plant in question in the same manner as in cherry-laurel).

Most of the experiments are carried out in conditions where light acts as a limiting factor. According to BLACKMAN only one factor can act as limiting and a reduction of the estimations to a definite temperature or CO_2 tension should therefore only take place when one or other of these factors is limiting. Still it is rather difficult to determine from the curves where these

¹⁾ Cf. also BROWN, W. H. and HEISE, G. W., Philippine Journ. of Science, C, 12, p. 1, 1917.

factors are limiting and where not and I have preferred to reduce all the estimations to 20° and to a CO_2 content of 0.55 mg pr. l. Since the temperature in the greater part of the experiments was about 20° , the values of the corrections are small. On the whole the assimilation curves will be about the same with or without the corrections (The respiration values are not corrected for the CO_2 content of the air).

The errors in the estimations are as follows:

1. Constant errors. By using very dilute solutions for titrations (for instance $\frac{n}{100} - \frac{n}{200}$) an error will arise since the water used in diluting acts as an acid. For instance: 20 cm^3 Baryta solution corresponded with $19.9 \text{ cm}^3 \frac{n}{22} \text{ HCl}$. After the solutions were diluted ten times, 20 cm^3 of the Baryta solution corresponded with $19.4 \text{ cm}^3 \frac{n}{220} \text{ HCl}$. Yet the significance of this error is not great and can here be omitted.

More important is the error arising from the fact that not the whole amount of CO_2 is absorbed in the absorption tubes. The magnitude of this error will be different for every single apparatus. To estimate this error two methods can be used. Indirectly, the error can be estimated by passing a definite amount of air through the apparatus and titrating the content of each absorption tube separately. The result of 3 experiments with 3 different systems of absorption tubes was as follows.

Content of the absorpt. tubes	Tube 1	Tube 2	Tube 3	Tube 4
$30 \text{ cm}^3 \frac{n}{220} \text{ Baryta sol.} \dots$	59	28	13	—
» » » » ..	69.7	21.5	8.8	—
$40 \text{ cm}^3 \frac{n}{110} \text{ Baryta sol.} \dots$	44.3	27.1	17.4	11.2

The figures indicate percent of the total amount of the absorbed CO_2 . Hence it can be calculated, that the loss of CO_2 in the first experiment is 11 %, in the second 9 % and in the third 20 % of the estimated value.

In the last experiment the diameter of the absorption tubes was greater than in the 2 first experiments. To accomplish an effective absorption the absorption tubes should be narrow and the gas-bubbles small.

Directly, the error can be estimated by comparing the apparatus with another of greater accuracy. Thus I estimated the respiration for leaves of *Sambucus* to 0.405 mg CO₂ pr. hour pr. 100 cm². At the same time an estimation was carried out with the apparatus, described in my paper (1912 p. 21). The respiration was estimated at 0.426 mg CO₂. The error in this last apparatus is about + 5 %; the right value for the respiration in the leaves of *Sambucus* is therefore 0.46 mg CO₂ and the error in the assimilation apparatus is about 13 %. Further I tried to estimate the CO₂ content of pure anhydrous Na₂CO₃. 0.5 g of this substance was dissolved in 1 l. of water. 5 cm³ of this solution + 5 cm³ $\frac{n}{44}$ HCl was poured into a tube, fitted in place of the receiver, and an air current, free from CO₂, was passed through the apparatus. In the 5 cm³ of the Na₂CO₃ solution was 2.5 mg Na₂CO₃, corresponding with 1.04 mg CO₂. By titration of the content of the absorption tubes I found in two experiments 1.04 and 1.06 mg CO₂. Here a deficiency of absorption could not be detected.

2. The accidental errors of the apparatus arise from the titrations. Every estimation of the CO₂ assimilation is obtained as a difference between 2 titrations. The standard deviation (σ) on each titration is about 0.07 cm³ and on the difference 0.1 cm³. When $\frac{n}{110}$ HCl is used, 0.1 cm³ corresponds with 0.02 mg CO₂. The experimentation time is in this case 1 hour, and the leaf area should be so great, that about 0.4—0.5 mg CO₂ is assimilated.

Supposing that the error arising from the deficiency of absorption is about 10 %, and the value of the standard deviation 0.02, the corrected value for the CO₂ assimilation is $(a + 0.1 a) \pm 0.02$, when a is the amount of CO₂, assimilated during the experimentation time. The corrected value is then calculated per hour per 100 cm² leaf area. (In the tables I—VIII the column "CO₂ assimilated" indicates the values directly found, increased by 10 %).

I am inclined to believe that the error on the corrected values will not surpass about 5 % of the value; at any rate the accuracy of the apparatus can not be said to be very high; but it should be remembered, that the apparatus from the beginning was adapted for field-work and short experimentation times. The last point is of importance. Frequently experiments of lesser accuracy with unaltered plants are to be preferred to experiments of greater accuracy with plants, that on account of a long experimentation time are altered in uncontrollable ways. On the other hand the accuracy of the apparatus can be increased to any desired degree by using for

instance vessels of greater capacity, say 5 l., an experimentation time of 5 hours and $\frac{n}{22}$ solutions.

Producing different intensities of light. When studying the influence of light on CO_2 assimilation one should be able to vary the intensity of light. Variations were obtained by covering the receiver with the leaf with screens of different transparency. Paper screens that were used at first are not suitable because they do not absorb the different rays in the same degree. The best screens are prepared from photographic plates, faintly illuminated and developed in the usual manner. By preparing a series of such screens and combining them, different intensities of light can be produced.

Although estimations in subdued light are carried out with facility, it is rather difficult to determine the CO_2 assimilation in direct sunshine. The temperature in the plant receiver easily rises too high and the leaf is injured. Yet the determinations can be carried out with the following precautions. The receiver is fitted in a stand, 30 cm above the table. The sunlight is filtered through a shallow disc with water, applied some cm above the receiver. It is still better to use the arrangement in my experiments with *Sinapis*: as receiver to use a glass tube surrounded with another glass tube with side tubes, through which a water current passes during the experiment.

2. Estimation of the intensity of light. When experiments on the relation between CO_2 assimilation and the intensity of light are to be carried out, it is necessary to make determinations of the intensity of illumination. WIESNER (1907) who especially has investigated this question, used silverchloride paper after the method of BUNSEN-ROSCOE; but this paper loses its sensibility very quickly and must be prepared anew every day; therefore both WIESNER and other investigators have, besides the silverchloride paper, used photographic papers of different kinds.

When I studied the influence of light upon forest-trees, I used WYNNES photographic exposure-meter, which is also used by several others (RÜBEL 1908 p. 13.)

Estimations with this apparatus are carried out in this manner, that the time, in which a sensitive paper is coloured to the same degree as the standard tints on the meter, is measured. This time is inversely proportional to the intensity of illumination. When the paper is coloured in 5 minutes, the intensity of illumination is $\frac{1}{5}$; in order to obtain convenient values this figure may

be multiplied with 100; so in this case the intensity of illumination is 20. The time, that is used for colouring the paper, is measured by a stop-watch.

When a photographic paper is to be used for such estimations, it is necessary that $I \cdot t = \text{constant}$ ($I =$ the intensity of illumination, t the time to colour the paper). For the paper used in WYNNES Photometer, this seems to be the case with illuminations of greater intensity; with feeble intensities the time that is used for colouring the paper seems to be somewhat greater than the theoretical time.

The paper used in WYNNES Photometer is like most photographic papers more sensitive to blue than to red light. This error I have tried to diminish by covering the Photometer with a yellow glass to absorb part of the blue rays. Still WYNNES' photometer is not satisfactory, and in my last experiments I have used another paper, Rhodamin B paper, to estimate the intensity of illumination. The advantage of this paper is that it is very sensitive to the red part of the spectrum.

The Rhodamin B paper was at first prepared by ANDRESEN (1898). It is a silver bromide paper, sensitized with Rhodamin B. ANDRESEN used it for the estimation of sunlight and WIESNER also has used it for estimations of relative illumination. It is prepared as follows (the description in WIESNER (1907) is wrong): Raw paper for photographic use (for instance 12 kg Rives) is immersed in a solution of 6.1 % KBr for 5 minutes. After drying it is sensitized in a dark room by floating on a solution of 12 % AgNO_3 for 2 minutes. Next it is carefully washed out in distilled water to remove the excess of AgNO_3 . At this stage its sensibility to light is small and it is blackened very little by exposure. (The blackening of the unwashed paper is caused by the excess of AgNO_3 in the paper). When the washing out of the paper is finished, it is immersed for 5 minutes in a bath, consisting of 200 cm^3 water, 6 g NaNO_2 and 12 cm^3 of a solution of Rhodamin B in alcohol (1:200) (ANDRESEN uses 8 cm^3 of the Rhodamin solution). By the treatment with NaNO_2 the paper gets its sensibility to light back again; the Rhodamin B makes it sensitive especially to the yellow rays. Care should be taken that the papers do not cover one another in the bath. The prepared paper is red and is blackened quickly by exposure to light.

In estimations of light intensity it is of great significance to get a good standard colour. Such a colour can, I have found, be made by preparing paper in the manner described above, but without NaNO_2 in the last bath. The appearance of the paper is

the same as that of the ordinary paper, but it blackens slowly and very slightly. By exposing it for 1—2 hours in direct sunshine it gets a colour that alters only slightly on further exposure. This colour can therefore, under conditions that I shall mention below, be used as a standard colour. After an exposure of a few seconds in direct sunshine the ordinary Rhodamin B paper will acquire precisely the same tone.

Further it is necessary to prepare an apparatus that can be used for the exposure of the sensitive paper.

I use an apparatus of similar construction to that of WIESNER (1907). It consists of 3 sheets of card-board of the same size, stuck together along one of the edges. In the 2 upper sheets a rectangular aperture (1×2 cm) is cut out. A strip of the paper with the standard colour is arranged between the two upper sheets, covering half of the aperture, while the sensitive paper is put in between the two

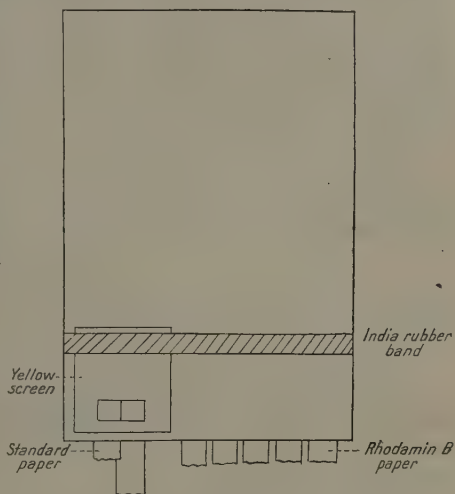


Fig. 2. Exposuremeter.

lower sheets, covering the other half part of the aperture. By pulling the end of the sensitised paper new parts of it can be brought before the aperture. When the whole strip is exposed, it can be replaced with fresh strips without opening the apparatus. A band of india rubber holds the sheets together.

As mentioned above the Rhodamin B paper is sensitive to the red part of the spectrum. Still the sensibility to the blue rays is great. It is therefore an advantage to remove a part of the blue rays by filtering the light to be estimated through a yellow screen in the same way as is done in photography. As yellow filter I use a 0.025 % solution of potassiumbichromate in a thickness of 1 cm. It is more convenient and for many purposes sufficiently accurate, to use films coloured with picric acid. Yet such a filter is not very stable.

For estimations of the relative intensity of light the apparatus can be used without further measures. Although the standard colour is not quite stable, it is of no significance in that respect. When for instance the relative illumination in a forest is to be estimated, (viz. the illumination in the forest in percent of the free daylight) an estimation is at first carried out in an open place and later in the forest. Since the light in the forest is not uniform, the exposure-meter should be carried around in the forest during the estimation (BOYSEN JENSEN 1910 p. 12). The alteration of the standard colour during 2 consecutive estimations is imperceptible.

On the other hand the apparatus can not be used directly for absolute estimations of the intensity of light. That is only possible by preparing an unalterable standard colour that can easily be reproduced. This I have so far not succeeded in doing. When therefore absolute estimations are to be carried out with the apparatus described above, it is necessary to compare the apparatus with that of WIESNER and to express the estimations in BUNSEN's units. Such a comparison should be carried out from time to time and always under the same conditions. I do so in direct sunshine. An intensity of light that can darken BUNSEN's silver chloride paper to the standard colour in 1 sec. is taken as being 100.

I have determined the intensity of light in the different hours of 5 days in the months of July and August, partly with and partly without sunshine. The mean of this estimations that give only a rough idea of the daily course of the intensity of light in these months, is as follows:

Hours.	Intensity of light.
12—1	39
1—2	38
2—3	36
3—4	33
4—5	29
5—6	22
6—7	14
7—8	4

3. Estimation of the respiration. The amount of CO_2 given off by the plants in respiration can be measured by the apparatus mentioned above. More easily the determinations can be made with the following apparatus. The plant is enclosed in a glass jar, closed with a glass lid or with a cork stop impregnated with paraffin. The dimensions of the jars should be in proportion to the intensity

of respiration of the plants. Care must be taken that only a part of the oxygen in the jars is used by the plants. The plant material must not touch the bottom, so it is fitted either in a bottle of gauze, hanging from the lid, or it is put on a perforated disk of paper or cork, held up from the bottom by needles.

In the bottom is the absorbing fluid. When the plant material is little, $\frac{n}{7} - \frac{n}{22}$ Baryta solution is to be used; with more plant material NaOH solution in greater or less concentration. When a suitable time has elapsed the amount of the CO_2 absorbed is determined by titration. If baryta solution be used the fluid can be titrated directly with HCl; if NaOH solution, the absorbed CO_2 must first be precipitated with BaCl_2 after the method of SØRENSEN and ANDERSEN (1908 p. 279).

The absorption of the CO_2 given off by the plants takes places very quickly.

Example. Leaves of *Rumex acetosella*, area = 48 cm^2 .

The leaves were put in a glass jar, vol = 100 cm^3 , in the bottom of the jar 1 cm^3 ca. $\frac{n}{7}$ baryta solution, corresponding to 2.85 cm^3 $\frac{n}{22}$ HCl.

The jar with the leaves was placed in darkness for 6 hours at 17° .

The titration value was then 1.15 cm^3 HCl; the CO_2 given off by the leaves is $2.85 - 1.15 = 1.7 \text{ mg CO}_2$:

Respiration pr. 100 cm^2 pr. hour = 0.59 mg CO_2 .

4. Estimation of the dry matter. This estimation is made in the usual way by drying the plant material first at 60° until most of the water has evaporated and then at 100° to constant weight.

5. Direct estimations of the production of matter. From the above mentioned estimations it will be possible to calculate the amount of dry matter produced pr. unit of area pr. 24 hours. In order to check the obtained value it is also possible sometimes to measure directly the production of organic matter.

In the propagation of diatoms for instance the new diatoms can assimilate CO_2 in the same manner as the parents and the production of organic matter will always be proportional to the amount of diatoms. The reproduction is progressive, if none of the diatoms are destroyed. Supposing that the amount of diatoms is

a , that x percent of the diatoms divide every day and that none of the diatoms are destroyed, the amount of diatoms after p days will be $m = a (1 + \frac{x}{100})^p$; x is the percent production of matter per day. In this equation m , a and p can be determined, hence x can be calculated. For instance, when the amount of diatoms in a certain volume of water at the beginning of the experiment is 100 and after 10 days 1000, the daily percent production can be calculated from the equation $100 (1 + \frac{x}{100})^{10} = 1000$; x is found to be 25.9. 25.9 % of the diatoms divide therefore every day.

In a similar manner the percent production of matter can also be found for higher plants, but only, when the whole or at any rate a constant part of the new built organic matter is used to form leaves. This condition is fulfilled in young seedlings, — for instance in *Sinapis alba*.

The determination of the percent production of matter by *Sinapis alba* is carried out in the following way.

The dry weight of 100 seeds of *Sinapis* is 0.5 g.

2 *Sinapis* plants, who had grown from 5—27 Juni, 22 days, (the time of germinating is not included) contained 0.442 g dry matter, per 100 plants 22.1 g.

The percent production of matter can then be calculated from the equation

$$0.5 (1 + \frac{x}{100})^{22} = 22.1$$
$$x = 18.8 \%$$

3. Earlier experiments on the influence of light on CO₂ assimilation.

Of investigations regarding the influence of light on CO₂ assimilation I shall mention only the most recent¹⁾.

PANTANELLI (1903) dealt with the influence of light on the bubbling rate in *Elodea*. The result of his experiments is recorded in a curve (Pl. IV in his paper; cf. also Blackman and Smith 1911 pag. 408). He finds that the CO₂ assimilation is proportional to the light intensity until about sunlight. At greater intensities of light the CO₂ assimilation is diminished. The curve representing the relation between intensity of light and CO₂ assimilation is therefore

¹⁾ A detailed account on the influence of light on plants may be found in COMBES (1910 p. 75).

according to PANTANELLI an optimum curve. The position of the optimum is influenced by the CO_2 content of the water.

In a series of papers BLACKMAN (1905, 1911) and his students have investigated the influence of CO_2 supply, light intensity and temperature on CO_2 assimilation in land and water plants. The result of his experiments is that "the magnitude of this function in every combination of these factors is determined by one or other of them acting as a limiting factor". For instance let us consider the influence of light on the CO_2 assimilation at a temperature of 20° and a CO_2 content in the air of 5 %. The curve representing the relation between light intensity and CO_2 assimilation will at first be a straight line, the CO_2 assimilation rising in proportion to the intensity of light. At a certain point the curve will attain a maximum and further it will be parallel to the abscissa line. Here the temperature and not the light intensity is acting as limiting factor and only a rise of the temperature will produce a rise in the CO_2 assimilation. Hence it appears that the position of the maximum is influenced by the temperature: at lower temperatures the maximum will also lie at a lower intensity of light. An "optimum" of light intensity according to BLACKMAN does not exist.

An investigation of the influence of light on the CO_2 assimilation in light and shadow plants is carried out by WEIS (1903). The leaves were enclosed in a test tube in air supplied with CO_2 . After the exposure of the plant the air was analysed by the method of BONNIER-MANGIN. The intensity of light was measured with photographic paper. The result of the experiments was as follows (CO_2 assimilation in $\text{cm}^3 \text{CO}_2$ pr. 1 cm^2 pr. hour).

	<i>Oenothera.</i>	<i>Polypodium.</i>
Sunlight.....	0.1660	0.0650
$\frac{1}{80}$ sunlight	0.0517	0.0705
$\frac{1}{100}$ sunlight	0.0270	0.0420

In sunlight the CO_2 assimilation is 2—3 times greater in *Oenothera* than in *Polypodium*; in $\frac{1}{80}$ sunlight the CO_2 assimilation is higher in *Polypodium*. That agrees very well with the results obtained in my experiments.

The investigations of COMBES and several others on the influence of light on the production of matter will be referred to later.

4. The production of matter in light plants.

Let us turn to the estimation of the production of matter in light plants in the manner described above. After some preliminary investigations I chose the 4 following plants for my experiments, viz. *Sinapis alba*, *Senecio silvaticus*, *Rumex acetosella* and *Sambucus*

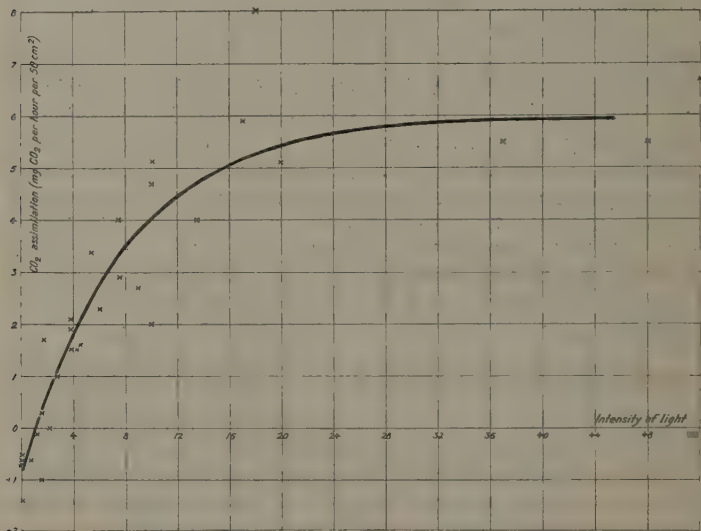


Fig. 3. CO₂ assimilation in *Sinapis alba*.

nigra. The plants used in my experiments were all grown in full daylight.

1. CO₂ assimilation. The results of the estimations of the CO₂ assimilation in the 4 plants are printed in Tables I—IV. As mentioned above the different estimations are reduced to a temperature of 20° and a CO₂ tension of 0.55 mg per l. The figures are recorded as curves in fig. 3 and 4. In the curves the abscissae indicate the intensity of light in BUNSEN's units $\times 100$ and the ordinates the CO₂ assimilation in mg per hour per 50 cm² of the upper surface + 50 cm² of the lower surface.

For *Sinapis alba* (fig. 3) the different estimations are marked out. As it might be expected the variability is rather great. The reason is partly, that the error in the estimations as mentioned

above may rise to about $\pm 5\%$ of the value; partly, that the plant material used in the experiments is not uniform. Certainly the shape of the curve varies with the surrounding conditions, especially with the intensity of light, in which the plants are grown. As a matter of fact the irregularity in the estimations can be made less by using uniform material. I have not laid stress on this point. It was more important for me to get the extreme values also.

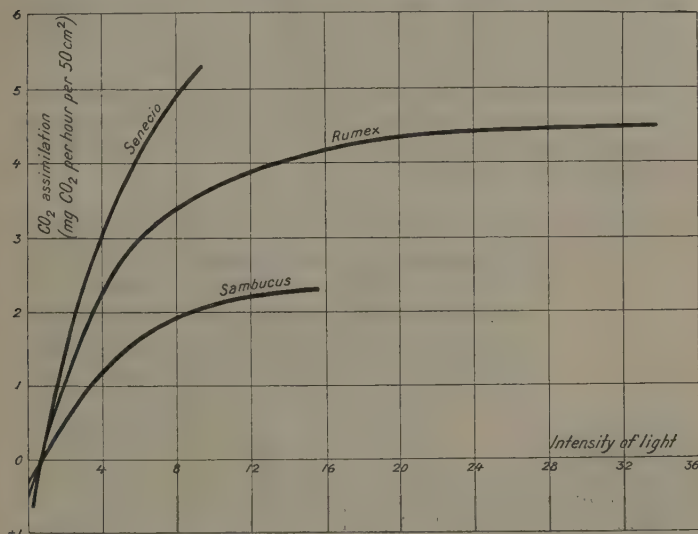


Fig. 4. CO₂ assimilation in *Senecio silvaticus*, *Rumex acetosella* and *Sambucus nigra*.

The shape of the assimilation curves in the 4 plants is as follows: The curves begin below the axis of abscissae, which is crossed at some distance from the zero point; the first part of the curves is about linear, next they bend gradually and become finally about parallel to the axis. On the whole the curves are identical with those found of BLACKMAN for the influence of light on the CO₂ assimilation. In the first part, light is the limiting factor and in the last part an other factor (temperature or CO₂ supply) is limiting. Between these two parts there is a third part of considerable extent where the CO₂ assimilation is neither constant nor proportional to the light intensity; here the different factors interact. According to the investigations of MITSCHERLICH (1909, p. 537 and 1911 p. 231) similar curves are obtained from studying the influence of nutritive

substances or climatic factors on the production of matter. MITSCHERLICH formulates the minimum law of LIEBIG as follows: The amount of the crop rises on increasing the supply of a nutritive substance acting as limiting factor but the increase is not proportional to the supply but decreases gradually when approaching the point where the factor in question is no more limiting.

The curves are characterised by 3 points: 1. The value for the light intensity 0 (= the respiration of the leaves), 2. The intensity of light, in which respiration and CO₂ assimilation are in equilibrium, and 3. The maximum value for the CO₂ assimilation.

Considering the assimilation curves it is obvious that the difference between them is small. Only the curve for the sun leaves of *Sambucus* has lower values than the other 3. The values for the 3 cardinal points is as follows:

	Respiration, mg per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surface	Intensity of light, in which respira- tion and CO ₂ as- similation are in equilibrium	The maximum value of the CO ₂ assimilation per 50 cm ² of the up- per surface + 50 cm ² of the lower surf.
<i>Sinapis alba</i>	0.8	1.0	6.0
<i>Senecio silvatic.</i> ..	0.7	0.6	?
<i>Rumex acetos.</i>	0.5	0.5	4.5
<i>Sambuc. nigra</i> (sun leaves)	0.3	0.7	2.3

It is now of interest to compare the maximum value with that obtained by other investigators (cf. the table pag. 241).

It may be seen that the difference between the estimations of the different authors is considerable. In reality the estimations can without difficulty be divided into two groups: those that are carried out by the half leaf method of SACHS and those that are carried out with the air current method of KREUSSLER. With the first method the value of the CO₂ assimilation is estimated to about 15 mg CO₂ per 50 cm² per hour, with the latter to 4—6 mg. As might be expected the values obtained in my experiments lies nearest to those obtained by GILTAY and BROWN and ESCOMBE.

As pointed out by THODAY the reason for these discrepancies may be sought for in the difference in the surrounding conditions, especially the temperature. The values obtained by BROWN and

Investigator	Method	Plant	Light	Temperature	CO ₂ assimil. pr. 50 cm ² pr. hour
SACHS	Half leaf method	<i>Helianthus</i>	Sunshine	25°	13
	»	<i>Cucurbita</i>	—	24°	11
MÜLLER	»	<i>Nymphaea</i>	The illumination changing	—	18
		<i>Rumex</i>		—	17
		<i>Petasites</i>		—	15
		<i>Helianthus</i>		—	14
		<i>Nicotiana</i>		—	10
		<i>Tulipa</i>		—	10
		<i>Arum</i>		—	8
		<i>Colchicum</i>		—	9
THODAY	»	<i>Helianthus</i>	Sunshine	about 27-29°	13
		<i>Catalpa</i>	»	»	4
WEBER	Estimation from the product of dry matter	<i>Tropæolum majus</i> ..	The illumination changing	—	3.3
		<i>Phaseol. multfl.</i> ..		—	2.4
		<i>Ricinus comm.</i> ..		—	3.9
		<i>Helianthus ann.</i> ..		—	4.1
GILTAY	Air current method	<i>Helianthus</i> (Wageningen)	The illumination changing	13-27°	2.9
		<i>Nicotiana</i> (Wageningen)		12-29°	2.2
		<i>Helianthus</i> ..		28-36°	3.8-4.0
		<i>Cassia</i>		28-35°	6.1
		<i>Cedrela</i>		28-34°	4.5
		<i>Nicotiana</i> ..		31-35°	4.5
		<i>Acalypha</i> ..		33-35°	3.5
BROWN and ESCOMBE	»	<i>Helianthus</i>	Diffuse light	ca. 20°	3.4
		<i>Tropæolum</i>	Sunlight with canvas screen	20-25°	1.7
		<i>Catalpa</i>	Intermittent sunshine	ca. 20°	3.0
		<i>Polygonum Weyrichii</i>	Sunlight with canvas screen	ca. 20°	3.8
BOYSEN JENSEN	»	<i>Sinapis alba</i>	Excess of light at 20° and with a CO ₂ content of 0.55 mg pr. l.	20°	6.0
		<i>Senecio silv.</i>		20°	—
		<i>Rumex acetos.</i>		20°	4.5
		<i>Sambuc. nigra</i> (sun leaves)		20°	2.3

ESCOMBE and by me¹⁾ agree very well, and the intensity of the CO₂ assimilation in quickly growing light plants can be estimated at 4—6 mg per 50 cm² per hour by 20°. The objection urged by THODAY against the experiments of BROWN and ESCOMBE that the leaves in their experiments not were fully turgid, can scarcely be maintained against my experiments. On the other hand the experiments of SACHS and THODAY aimed at estimating the greatest possible CO₂ assimilation; these experiments are carried out in direct sunshine; the air temperature in the experiments of THODAY was 27—29° and the leaf temperature will probably have been some degrees higher. When we calculate the results of the experiments obtained by the air current method at a temperature of 35° we will (if the light or the CO₂ supply do not act as limiting factors at this temperature) get a value of about 18 mg CO₂. Hence it appears, that the difference in the values obtained with the two methods is not so great as it might appear. But to consider the values obtained by SACHS and THODAY as the mean for the CO₂ assimilation over a longer period of time will not be correct. First the sun does not shine every day, and it is only in direct sunshine that the high leaf temperatures occurs, and for the second, in a protracted period of sunshine the plants will quickly come to suffer from lack of water, the stomata will be closed and the CO₂ assimilation will be diminished. I have found that to be the case in the month of June in 1917 in Denmark. Indeed a CO₂ assimilation of 18 mg per 50 cm² would mean a production of dry matter higher than has ever been found in our climate. I shall return to that point below.

From the assimilation curves given in the figs. 3 and 4, the curves for the real assimilation (the apparent assimilation + the CO₂ given off by respiration) can easily be constructed by displacing the curves parallel to the vertical line until they begin at the zero point.

2. Respiration. As will be seen from the curves the respiration for the leaves of the four plants is the following (mg CO₂ per 50 cm² of the upper surf. + 50 cm² of the lower surface):

Sinapis alba 0.8

Senecio silvaticus 0.7

Rumex acetosella 0.5

Sambucus nigra (sun leaves) 0.3

¹⁾ To be sure I have not worked with *Helianthus*; but I am inclined to believe that the CO₂ assimilation for this plant will not be greater than for *Sinapis*.

(In *Helianthus* BLACKMAN found 0.7 mg CO₂ per hour per 50 cm² at 19°).

Hence it may be calculated that the maximal CO₂ assimilation is about 8 times as great as the respiration.

In the stems of *Sinapis alba* the respiration was estimated as 0.16 mg CO₂ per 1 g per hour (20°).

3a. Percent production of matter calculated. From the data given above it is possible approximately to calculate the percent production of matter, this value being defined in the manner stated on page 219. We will work out the calculation in *Sinapis alba* for the month of July. A determination of the average intensity of light in the different hours of a day in this month is given on page 234. The average temperature in July is reckoned as 20° to facilitate the calculations. To the sure the mean temperature for this month is in Denmark only 16.0°. But in sunshine the leaf temperature will be some degrees above the temperature of the air.

The calculations are carried out for a plant with a leaf area of 100 cm² (upper + lower surface). Such a plant was found to have the following composition.

	Weight.	dry matter.
Leaves	1.30 g	0.168 g
Stem + root	0.96 g	0.111 g
	2.26 g	0.279 g

HORNBERGER (1885 p. 415) found in *Sinapis* grown for 28 days, for a leaf area of 50 cm²:

	Weight.	dry matter.
Leaves	—	0.170 g
Stem + root	—	0.075 g
	2.24 g	0.245 g

The result of the calculations is as follows:

Gain of dry matter: Assimilation.		
Time	Intensity of light in Bunsen units	Real Assimilation (per hour per 50 cm ²)
12—1	39	6.7
1—2	38	6.7
2—3	36	6.7
3—4	33	6.7
4—5	29	6.6
5—6	22	6.4
6—7	14	5.6
7—8	4	2.6

48.0 mg CO₂ assimilated per $\frac{1}{2}$ day
per 1 day per 50 cm² 96 mg = 60 mg dry matter.

Loss of dry matter: Respiration.

Leaves $24 \times 0.8 \dots\dots\dots = 19 \text{ mg}$

Stem + root $24 \times 0.96 \times 0.16 = 4 \text{ -}$

$23 \text{ mg CO}_2 = 14 \text{ mg dry matter.}$

The production of dry matter per 50 cm^2 per day $= 60 - 14 = 46 \text{ mg} =$
 16.5% of the dry matter of the plant.

In a similar manner it will be possible to calculate the percent production of dry matter also for the other months of the year, when the intensities of light are known."

3b. Percent production of matter, directly estimated. It was mentioned above (page 235) that the percent production can also be estimated directly, but only when the whole, or at any rate a constant part of the new built organic matter is used in forming leaves, so that the production of matter is always proportional to the dry matter of the plant (which is not the case when flowering begins). The experiments were carried out in such a way that plants of *Sinapis alba* were grown in a flower pot until 2—4 leaves had appeared, when the dry matter of the plants was estimated. The vegetation time was reckoned from the time when the cotyledons expanded (about 8 days after the sowing of the seeds) until the termination of the experiment. The percent production of matter was calculated after the method given on page 236. The result of the experiments was as follows:

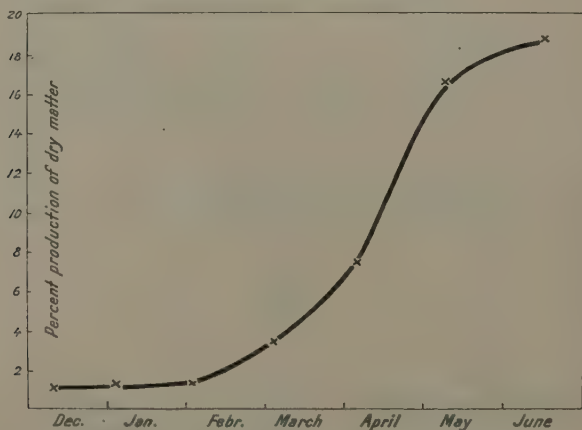


Fig. 5. Percent production of dry matter in *Sinapis alba*.

Vegetation time	Number of plants	100 seeds dry matter	Dry weight of 100 plants	Percent production of matter	
1 Decbr.—20 Decbr...	15	0.5 g	0.61	1.05	} Only the cotyledons expanded
22 Decbr.—15 January	12	—	0.68	1.30	
21 January—14 Febr.	5	—	0.68	1.30	
19 Febr.—14 March...	4	—	1.10	3.50	
21 March—20 April ..	6	—	4.43	7.50	} 4—6 leaves expanded
24 April—22 May	1	—	37.60	16.70	
5 June—27 June	2	—	22.10	18.80	

The points are plotted in the curve fig. 5.

The percent production of matter, calculated, is in July 16.5 %

The percent production of matter, directly estimated, is in June 18.8 %.

The agreement between the two figures is very satisfactory.

We will now compare these results with those obtained by other investigators.

WEBER tried to estimate the CO₂ assimilation in the manner described above (page 222). From his figures we can also calculate the percent production of matter:

Plant	Vegetation time	Dry matter at the beginning of the experiment	Dry matter at the termination of the exp.	Percent production of dry matter per day
<i>Tropaeolum majus</i> I....	50	0.052	9.090	} 10.9 %
» » II....	50	0.052	8.957	
<i>Phaseolus multiflorus</i> ...	48	0.376	6.212	6.0 %
» »	48	0.376	9.279	6.9 %
<i>Ricinus communis</i>	49	0.128	20.546	10.9 %
<i>Helianthus annuus</i>	43	0.093	29.899	14.4 %

In a paper by HORNBERGER (1885 p. 415) the production of dry matter in *Sinapis* is dealt with. The seeds were sowed on April 24. Presuming that the germination lasted 6 days we can reckon that the production of matter began on May 1.

The content of dry matter per 100 plants was on May 26, 12.5 g and on the June 2, 41.1 g. Hence it can be calculated that the percent production of matter per day was 13.2 and 14.3. (In

my experiments the percent production at the same time of year was 16.7).

LUBIMENKO (1908 p. 321) and COMBES (1910 p. 75) have investigated the production of matter in different intensities of light. From COMBES' paper I have calculated the percent production of dry matter per day as follows:

Plant	Beginning of the experiment		Termination of the experiment		Number of days	Percent production of dry matter
	Date	Content of dry matter	Date	Content of dry matter		
<i>Triticum vulgare</i>	Apr. 19	0.019	May 24	0.174	35	6.5 %
» »	»	—	July 5	1.612	77	5.9 %
<i>Raphanus sativus</i>	»	0.013	May 8	0.25	19	16.8 %
<i>Pisum sativum</i> ..	Apr. 22	0.127	May 9	0.335	17	5.9 %
<i>Tropæolum majus</i>	June 11	0.087	June 22	0.28	11	11.2 %
» » »	June 22	0.28	July 22	12.07	30	13.4 %
<i>Salsola Kali</i>	May 24	0.117	June 17	1.178	24	10.1 %

According to these investigations the percent production of dry matter may be 10 % to 17 % for quickly growing plants (*Helianthus*, *Ricinus*, *Raphanus*)¹⁾.

WEBER calculates the CO₂ assimilation in *Helianthus* as 4.1 mg CO₂ per 50 cm² per hour, what also corresponds with a percent production of matter of 14.4 %. In my opinion that is a proof that the mean CO₂ assimilation per 50 cm² per hour for quickly growing plants is about 4—6 mg and that the values found by SACHS and THODAY only hold good for exceptionally favorable conditions, especially very high temperatures, which SACHS also has pointed out. It is desirable that more experiments be carried out with WEBER's method and that the half leaf method of SACHS also be used in less favorable conditions.

4. The production of matter in the different phases of development. From the results given in HORNBERGER's paper we can follow the content and the production of dry matter during the life of a *Sinapis* plant. The figures are plotted in the curve fig. 6. The seeds were sowed on April 24. During the first six weeks, until about June 6, the shape of the curve is logarithmic. During this time the new built organic matter is used mainly for the formation of leaves; hence the production of dry matter

¹⁾ Further investigations on the production of matter in different plants may be found in Landw. Jhrb. V—IX 1876—80.

will be on the whole proportional to the dry matter of the plant. By and by, when a part of the new built matter is used more for the formation of stem and root, that consumes matter instead of producing it the dry matter of the plant will increase more slowly. As a fact, the shape of the curve from June 6 to July 20 is almost rectilinear. In the first part of August the leaves are lost. Hence the production of matter will cease and, as may be seen from the curve, the dry matter content of the plant will diminish, partly

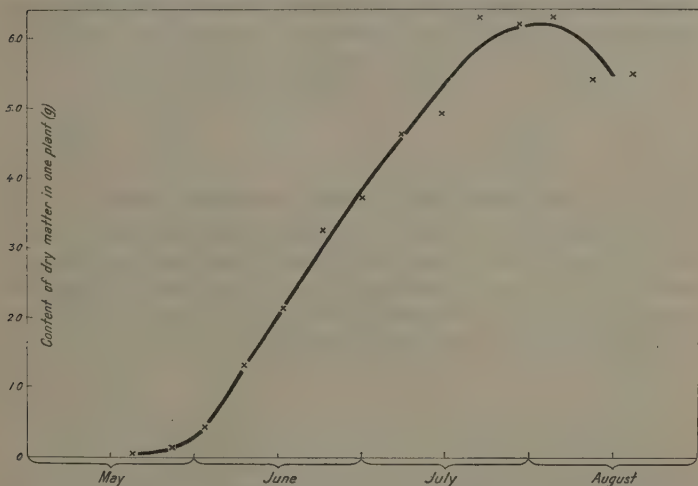


Fig. 6. The content of dry matter in the different phases of development in *Sinapis alba* (HORNBERGER).

because of the loss of the leaves and partly because the respiration of the stem, root and seeds goes on for some time.

5. Production of matter per unit of area. Finally I will give some figures for the production of dry matter in *Sinapis* per hectare, taken from HORNBERGER's paper. The seeds were sowed on April 24, 7 kg per ha, and the experiment lasted until Aug. 18. In this time the production of dry matter per hectare in kg was as follows: (The figures indicate the greatest values, not always the value at the termination of the experiment).

Leaves	857 kg
Stems	5856 -
Shells	2255 -
Roots	311 -
<hr/>	
9279 kg	

The loss of dry matter by respiration can not be estimated accurately. From the figures given on page 242 it may be calculated that the daily loss of dry matter is 7.1 % of the dry matter of the leaves and 2.4 % of the dry matter of the stems. For one week the figures are about 50 % and 17 %. Now HORNBERGER has estimated the dry matter in the *Sinapis* plants from week to week; hence it is possible to make an approximate estimation of the loss of dry matter. From this it can be calculated that the loss of matter by respiration will be about 10.000 kg, but the value is uncertain. Then the total production of dry matter would be ca. 20.000 kg per ha. Only 1—2000 kg (10—20 %) are seeds.

5. The production of matter in shadow plants.

In a similar manner I have estimated the production of matter in shadow plants. I chose the following four plants for my experiments, viz. *Oxalis acetosella*, *Ajuga reptans*, *Senecio silvaticus* (shadow plants) and *Sambucus nigra* (shadow leaves). As a rule the leaves used in the experiments were grown in a light intensity as small as possible.

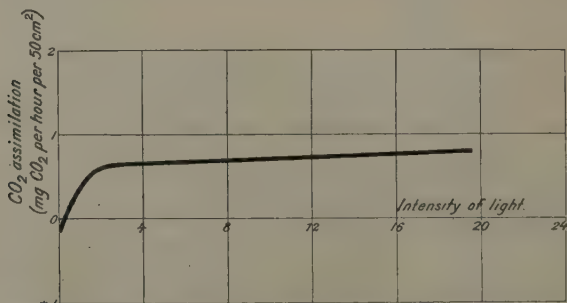


Fig. 7. CO₂ assimilation in *Oxalis acetosella*, *Senecio silvaticus*, *Sambucus nigra* and *Ajuga reptans*.

1. CO₂ assimilation. The results of the estimations are given in the tables V—VIII and in the curve fig. 7. The curves for the three plants are practically identical.

The values for the three cardinal points are the following:

	Respiration in the leaves, mg CO ₂ per hour per 50 cm ²	Intensity of light, in which the CO ₂ assimilation is 0	The maximal value of the CO ₂ assimilation per hour per 50 cm ²
<i>Sambucus nigra</i> (shadow leaves)	0.20	0.3	0.85
<i>Ajuga reptans</i> . . .	0.15	0.1	0.70
<i>Oxalis acetosella</i> ..	0.10	0.2	0.80

It will be seen that the values are small compared with those found for light plants.

2. Respiration. The respiration in the leaves of the three shadow plants varies from 0.1—0.2 mg CO₂ per hour per 50 cm².

MAYER (1892 p. 203, 441), who has previously investigated the respiration in leaves, found for shadow plants the following values:

	Oxygen con- sumption per 1 g dry matter	Tp.	Respir. in mg CO ₂ per 1 g dry matter (20°)
<i>Oxalis rosea</i>	0.86	21.7	1.54
<i>Poa nemoralis</i>	0.50	21.8	0.90
<i>Melampyrum pratense</i>	1.2	22.0	2.12
<i>Vaccinium myrtillus</i>	0.42	16.0	1.11

The figures in the last column have been calculated on the supposition that the value of the quotient $\frac{\text{CO}_2}{\text{O}_2}$ is 1.

Calculating from my own estimations on *Oxalis* in the same manner we will find that the leaves of this plant produce 1.44 mg CO₂ per 1 g dry matter.

In the rhizomes and leaf-stalks of *Oxalis acetosella* the respiration was estimated to 0.20 mg CO₂ per 1 g per hour (20°).

3. Percent production of matter. We will now try to calculate the percent production in *Oxalis* in the same manner as in *Sinapis*. The calculations are carried out for a plant with a leaf area of 100 cm² (upper + lower surface). The weight and dry matter content in such a plant are as follows.

	Weight	dry matter
Leaves	0.52	0.069
Leafstalks + rhizomes	0.85	0.165
	1.37	0.234

The result of the calculations (for full daylight) is:

Gain of dry matter (CO ₂ assimilation).		
Time	Intensity of light in <i>Bunsen</i> units	Real assimilation per hour per 50 cm ²
12—1	39	0.9
1—2	38	0.9
2—3	36	0.9
3—4	33	0.9
4—5	29	0.9
5—6	22	0.9
6—7	14	0.9
7—8	4	0.8

7.1 mg CO₂ assimilated per $\frac{1}{2}$ day;
per 1 day per 50 cm² 14.2 mg = 8.9 mg dry matter.

Loss of dry matter (respiration).

Leaves 24 \times 0.1 = 2.4 mg
Leaf-stalk 24 \times 0.85 \times 0.20 = 4.1

6.5 mg CO₂ = 4.0 mg dry matter.

The production of dry matter per 50 cm² per day = 8.9 — 4.0 =
4.9 mg = 2.1 % of the dry matter of the plant.

6. Summary.

Finally to summarise shortly the difference between *Sinapis alba* (a light plant) and *Oxalis acetosella* (a shadow plant):

In *Sinapis* the intensity of the CO₂ assimilation is very great, rising to at least 6 mg CO₂ per 50 cm² per hour at 20°. Also the respiration in the leaves is great, about 0.8 mg CO₂ per 50 cm² per hour at 20°. The point of equilibrium between CO₂ assimilation and respiration lies at a light intensity of 1.0 (BUNSEN units \times 100). The development of a *Sinapis* plant is very quick. In 4 weeks the dry matter content rises from 0.5 g to 38 g per 100 plants. In favourable conditions the daily percent production of dry matter can be estimated as about 15.

In *Oxalis* the maximal intensity of CO₂ assimilation is very small, about 0.8 mg CO₂ per cm² per hour at 20°. Also the respiration of the leaves is small, about 0.1—0.2 mg CO₂ per 50 cm² per hour at 20°. The point of equilibrium between CO₂ assimilation and respiration lies at a light intensity of 0.2. The daily percent production of dry matter is 2.1.

Febr. 9. 1918.

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Table I. *Sinapis alba*.

Nr.	Date	Area of leaf in square centimeters (upper + lower surface)	Rate of air current in minutes for 1 l	CO ₂ in air in mg per l	Mean CO ₂ content of air in the receiver	Temperature	CO ₂ absorbed per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surf.	CO ₂ absorbed corr. for temperature and CO ₂ content	Intensity of light (Bunsen's units)	Size of stomatal openings
1	1 ¹ / ₈ 16	14.4	25	0.58 ¹⁾	0.61	?	÷ 1.0	÷ 1.0	1.5	
2	»	14.4	26	0.58	0.45	?	4.2	5.1	9.0	
3	3 ¹ / ₈ 16	14.0	26	0.57	0.53	18°	1.3	1.5	3.8	
4	»	14.0	29	0.57	0.53	18°	1.2	1.5	3.8	
5	5 ¹ / ₈ 16	10.0	26	0.56	0.52	?	1.9	2.0	9.0	2
6	»	16.0	27	0.56	0.55	?	0.3	0.3	1.5	
7	7 ¹ / ₈ 16	40.0	27	0.59	0.59	18°	0.0	0.0	2.1	2
8	»	40.0	27	0.59	0.60	18°	÷ 0.1	÷ 0.1	1.2	2
9	»	40.0	29	0.59	0.65	18°	÷ 0.6	÷ 0.7	0	2
10	10 ¹ / ₈ 16	16.2	28	0.63	0.54	21°	2.4	2.3	6	2
11	»	16.2	27	0.63	0.56	20°	1.9	1.9	3.8	2
12	»	6.0	27	0.63	0.55	20°	5.9	5.9	17.0	2
13	10 ¹ / ₈ 16	16.6	30	0.72	0.59	20°	3.1	2.9	7.5	2
14	»	16.6	30	0.72	0.67	20°	1.2	1.0	2.7	2
15	»	16.6	30	0.72	0.64	20°	1.9	1.6	4.5	2
16	»	9.5	28	0.72	0.62	20°	4.5	4.0	13.5	2
17	23 ¹ / ₈ 16	8.4	27	0.61	0.48	26°	6.9	5.5	37	
18	4 ¹ / ₉ 16	40.6	—	—	—	16°	÷ 0.5	÷ 0.7	0	
19	5 ¹ / ₉ 16	66.2	—	—	—	15°	÷ 0.4	÷ 0.6	0	
20	8 ¹ / ₉ 16	64.0	—	—	—	20°	÷ 0.5	÷ 0.5	0	
21	9 ¹ / ₈ 17	34.0	32	0.57	0.40	16°	1.9	3.4	5.4	1—2
22	»	34.0	33	0.57	0.47	16°	1.1	1.7	1.7	1—2
23	»	34.0	32	0.57	0.67	16°	÷ 1.1	÷ 1.4	0	1—2
24	11 ¹ / ₈ 17	12.0	25	0.54	0.43	ca. 25°	4.2	4.0	7.5	1—(2)
25	»	6.4	24	0.54	0.43	ca. 25°	8.6	8.1	18	1—(2)
26	13 ¹ / ₈ 17	14.0	28	0.58	0.41	24°	5.2	5.5	48	2
27	»	14.0	26	0.58	0.42	25°	5.2	5.1	20	2
28	»	14.0	25	0.58	0.44	24°	4.8	4.7	10	2
29	13 ¹ / ₈ 17	4.4	26	0.54	0.47	24°	7.4	6.7	54	2
30	»	35.6	26	0.54	0.60	24°	÷ 0.8	÷ 0.6	0.7	2
31	25 ¹ / ₈ 17	19.8	30	0.55	0.47	23°	1.6	1.5	4.2	2
32	»	9.8	29	0.55	0.48	24°	3.0	2.7	9.0	1

¹⁾ Concerning the values for the CO₂ content of the air cf. page 227.

Table II. *Rumex acetosella*.

Nr.	Date	Area of leaf in square centimeters (upper + lower surface)	Rate of air current in minutes for 1 l	CO ₂ in air in mg per l	Mean CO ₂ content of air in the receiver	Temperature	CO ₂ absorbed per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surf.	CO ₂ absorbed corr. for temperature and for CO ₂ content	Intensity of light (Bunsen's units)	Size of stomatal openings
1	18/7 13	9.0	29	0.55	0.55	21°	0	0	2.4	
2	»	9.0	29	0.55	0.45	24°	4.6	4.3	13.5	
3	»	9.0	33	0.55	0.58	24°	÷ 1.2	÷ 0.9	0	
4	19/7 13	25.2	29	0.57	0.41	19°	2.6	3.7	18	
5	»	25.2	28	0.57	0.45	20°	2.0	2.4	4.5	
6	»	25.2	28	0.57	0.51	20°	1.0	1.1	1.5	
7	»	25.2	28	0.57	0.63	20°	÷ 1.0	÷ 0.9	0	
8	25/7 13	21.0	30	0.72	0.74	25°	÷ 0.4	÷ 0.2	0.3	
9	»	21.0	31	0.72	0.67	25°	0.9	0.5	1.8	
10	»	21.0	29	0.72	0.53	25°	3.8	2.9	13.5	
11	»	21.0	30	0.72	0.78	25°	÷ 1.1	÷ 0.8	0	
12	4/8 13	12.0	31	?	?	18°	2.2	2.5	36	
13	»	10.8	32	?	?	18°	4.1	4.7	36	
14	24/7 14	24.4	27	?	?	?	3.7	3.7	27	
15	»	24.4	27	?	?	?	0.4	0.4	2.1	
16	»	24.4	27	?	?	?	÷ 0.3	÷ 0.3	0	
17	25/7 14	34.2	29	?	?	16°	2.3	3.0	5.4	
18	»	34.2	29	?	?	16°	0.3	0.4	1.8	
19	»	34.2	29	?	?	16°	2.6	3.4	7.5	
20	»	34.2	29	?	?	16°	0.7	0.9	2.7	
21	»	34.2	29	?	?	16°	0.3	0.4	0	
22	26/7 14	60.0	—	—	—	17°	0.4	0.5	0	
23	31/7 14	32.0	27	0.62	0.49	25°	1.9	1.6	3.9	2
24	»	32.0	27	0.62	0.54	25°	1.1	0.8	1.2	2
25	»	32.0	27	0.62	0.68	25°	÷ 0.8	÷ 0.6	0	2
26	»	14.0	27	0.62	0.47	25°	4.8	4.2	15	2
27	5/8 14	48.0	—	—	—	17°	0.7	0.9	0	

Table III. *Sambucus nigra*, sun-leaves.

Nr.	Date	Area of leaf in square centimeters (upper + lower surfaces)	Rate of air current in minutes for 1 l	CO ₂ in air in mg per l	Mean CO ₂ content of air in the receiver	Temperature	CO ₂ absorbed per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surf.	CO ₂ absorbed corr. for temperature and CO ₂ content	Intensity of light (Bunsen's units)	Size of stomatal openings
1	30/7 13	44.0	32	0.75	0.56	22°	1.6	1.4	12.0	
2	»	44.0	30	0.75	0.65	23°	0.9	0.6	1.7	
3	»	44.0	33	0.75	0.80	23°	÷ 0.4	÷ 0.3	0	
4	»	44.0	30	0.75	0.65	?	0.9	0.8	60.0	
5	27/7 14	68.2	30	0.68	0.48	17°	1.2	1.6	8.1	2
6	»	68.2	30	0.68	0.56	17°	0.7	0.8	2.7	2
7	»	68.2	30	0.68	0.74	17°	÷ 0.4	÷ 0.5	0	2
8	30/7 14	52.0	27	0.59	0.44	24°	1.3	1.3	13.5	2
9	»	52.0	27	0.59	0.51	24°	0.7	0.6	3.3	2
10	»	52.0	27	0.59	0.42	30°	1.5	1.1	45.0	2
11	31/7 14	30.0	29	0.62	0.43	25°	2.6	2.5	15.0	
12	1/8 14	19.2	22	0.67	0.56	27°	3.1	2.0	13.5	
13	9/8 14	16.8	28	0.65	0.55	25°	2.6	1.9	15.0	
14	8/8 17	48.0	32	0.55	0.42	18°	1.0	1.5	5.4	0—1
15	»	48.0	31	0.55	0.49	19°	0.5	0.6	1.5	0—1
16	»	48.0	32	0.55	0.56	19°	÷ 0.1	÷ 0.1	0.6	0—1
17	»	48.0	31	0.55	0.62	20°	÷ 0.6	÷ 0.6	0	0—1
18	9/8 17	100.0	—	—	—	16°	÷ 0.7	÷ 0.9	0	
19	22/8 17	62.0	—	—	—	20°	÷ 0.4	÷ 0.4	0	
20	27/8 17	16.0	28	0.57	0.47	25°	2.7	2.3	6.0	2
21	»	26.0	28	0.57	0.54	20°	0.5	0.5	1.5	1—(2)
22	24/7 17	9.2	31	0.57	0.51	22°	2.5	2.4	ca.10.0	1
23	»	13.8	30	0.57	0.48	22°	2.6	2.6	7.0	1—2

Table IV. *Senecio silvaticus*, sun leaves.

Nr.	Date	Area of leaf in square centimeters (upper + lower surface)	Rate of air current in minutes for 1 l	CO ₂ in air in mug per l	Mean CO ₂ content of air in the receiver	Temperature	CO ₂ absorbed per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surf.	CO ₂ absorbed corr. for temperature and CO ₂ content	Intensity of light (Bunsen's units)	Size of stomatal openings
1	20/7 15	8.0	—	—	—	13°	3.3	5.4	6.8	
2	»	12.0	25	0.66	0.59	13°	2.8	4.3	7.5	2
3	22/7 15	14.0	28	0.72	0.66	16°	1.8	2.0	2.1	2
4	24/7 15	16.0	29	0.63	0.46	18°	4.4	6.0	12.0	2
5	»	16.0	30	0.63	0.59	18°	1.0	1.1	2.3	2
6	»	16.0	31	0.63	0.62	18°	0.2	0.2	0.6	2
7	»	16.0	31	0.63	0.65	18°	÷ 0.5	÷ 0.6	0	2
8	28/7 15	50.0	31	0.54	0.66	17°	÷ 0.9	÷ 1.1	0	
9	»	50.0	31	0.54	0.62	17°	÷ 0.6	÷ 0.7	0.2	
10	»	50.0	31	0.54	0.59	17°	÷ 0.4	÷ 0.5	0.6	
11	»	50.0	30	0.54	0.45	17°	0.7	1.0	2.4	
12	10/8 16	40.0	32	0.67	0.68	17°	÷ 0.1	÷ 0.1	0.8	
13	»	40.0	31	0.67	0.74	17°	÷ 0.7	÷ 0.9	0	

Table V. *Sambucus nigra*, shadow-leaves.

Nr.	Date	Area of leaf in square centimeters (upper + lower surface)	Rate of air current in minutes for 1 l	CO ₂ in air in mg per l	Mean CO ₂ content of air in the receiver	Temperature	CO ₂ absorbed per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surf.	CO ₂ absorbed corr. for temperature and CO ₂ content	Intensity of light (Bunsen's units)	Size of stomatal openings
1	29/7 13	70.0	34	0.74	0.57	20°	0.9	0.9	1.2	
2	»	70.0	33	0.74	0.65	21°	0.5	0.4	0.2	
3	»	70.0	?	0.74	0.74	21°	0	0	0	
4	»	70.0	32	0.74	0.58	21°	0.9	0.8	9.0	
5	5/8 13	82.0	31	?	?	21°	0.8	0.8	12.0	
6	»	82.0	35	?	?	21°	÷ 0.1	÷ 0.1	0	
7	»	82.0	31	?	?	21°	0.6	0.6	1.8	
8	»	82.0	35	?	?	21°	0.4	0.4	0.3	
9	»	82.0	35	?	?	21°	0.8	0.8	12.0	
10	29/7 14	80.0	—	—	—	21°	÷ 0.1	÷ 0.1	0	
11	29/7 14	104.0	29	0.63	0.48	18°	0.6	0.8	3.6	1—2
12	»	104.0	29	0.63	0.54	18°	0.4	0.5	1.2	1—2
13	»	104.0	29	0.63	0.66	18°	÷ 0.1	÷ 0.1	0	1—2
14	30/7 14	110.0	28	0.59	0.44	25°	0.6	0.6	13.5	2
15	»	110.0	28	0.59	0.45	25°	0.5	0.5	3.3	2
16	1/8 14	42.0	30	0.70	0.59	27°	1.1	0.7	13.5	
17	»	42.0	30	0.70	0.66	27°	0.4	0.2	1.0	
18	»	42.0	30	0.70	0.60	27°	1.0	0.6	3.6	
19	4/8 14	58.0	—	—	—	19°	÷ 0.1	÷ 0.1	0	2
20	5/8 14	48.0	—	—	—	17°	÷ 0.1	÷ 0.1	0	
21	5/8 17	163.0	20	0.61	0.49	23°	0.4	0.4	9.0	
22	»	163.0	20	0.61	0.63	23°	÷ 0.1	÷ 0.1	0.5	
23	»	163.0	19	0.61	0.72	23°	÷ 0.5	÷ 0.4	0	
24	6/8 17	90.0	33	0.56	0.50	19°	0.2	0.2	4.2	1—2
25	»	90.0	31	0.56	0.60	19°	÷ 0.2	÷ 0.2	0	1—2
26	»	90.0	30	0.56	0.48	20°	0.4	0.5	0.8	
27	28/8 17	78.0	31	0.44	0.31	20°	0.6	0.8	15.0	1—(2)
28	»	44.0	28	0.44	0.36	20°	0.8	1.0	22.5	1—(2)
29	26/8 17	94.4	29	0.55	0.64	24°	÷ 0.4	÷ 0.3	0	1
30	»	94.4	29	0.55	0.45	24°	0.4	0.4	1.8	1
31	»	94.4	29	0.55	0.49	24°	0.3	0.3	0.7	1
32	26/8 17	58.4	32	0.55	0.42	22°	0.8	0.9	3.0	2

Table VI. *Oxalis acetosella*.

Nr.	Date	Area of leaf in square centimeters (upper + lower surface)	Rate of air current in minutes for 1 l	CO ₂ in air in mg per l	Mean CO ₂ content of air in the receiver	Temperature	CO ₂ absorbed per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surf.	CO ₂ absorbed corr. for temperature and CO ₂ content	Intensity of light (Bunsen's units)	Size of stomatal openings
1	8/8 14	52.2	28	0.65	0.56	25°	0.7	0.5	9.0	1
2	14/8 16	46.2	24	0.47	0.38	?	1.0	1.4	ca. 6.5	0
3	28/8 16	60.0	29	0.54	0.41	?	0.9	1.2	0.5	0
4	1/8 16	76.0	24	0.54	0.55	?	÷ 0.1	÷ 0.1	0.4	1—(2)
5	»	76.0	23	0.54	0.56	?	÷ 0.1	÷ 0.1	0	1—(2)
6	21/7 16	80.0	27	0.57	0.46	20°	0.6	0.7	10.0	0
7	»	80.0	25	0.57	0.45	20°	0.7	0.9	10.0	0
8	»	80.0	25	0.57	0.54	20°	0.2	0.2	0.2	0
9	»	50.0	25	0.57	0.59	20°	÷ 0.1	÷ 0.1	0	0
10	12/8 16	65.0	25	0.65	0.51	21°	1.0	1.0	12.0	
11	»	65.0	24	0.65	0.58	21°	0.5	0.4	2.1	
12	»	65.0	33	0.65	0.54	21°	0.6	0.6	3.0	
13	18/8 16	74.0	31	0.56	0.44	20°	0.6	0.8	3.0	
14	»	74.0	30	0.56	0.58	20°	÷ 0.1	÷ 0.1	0	
15	»	74.0	31	0.56	0.49	19°	0.4	0.5	1.4	
16	»	74.0	30	0.56	0.54	19°	0.1	0.1	0.3	
17	»	74.0	30	0.56	0.57	19°	÷ 0.1	÷ 0.1	0	
18	»	74.0	30	0.56	0.54	19°	0.1	0.1	0.3	
19	17/8 16	40.0	30	0.57	0.50	21°	0.7	0.7	13.5	
20	»	40.0	30	0.57	0.51	22°	0.6	0.6	1.8	
21	»	40.0	30	0.57	0.51	22°	0.6	0.6	2.4	
22	»	73.0	—	—	—	—	÷ 0.1	÷ 0.1	0	
23	18/9 16	340.0	—	—	—	13°	÷ 0.1	÷ 0.2	0	

Table VII. *Senecio silvaticus*, shadow leaves.

Nr.	Date	Area of leaf in square centimeters (upper + lower surface)	Rate of air current in minutes for 1 l	CO ₂ in air in mg per l	Mean CO ₂ content of air in the receiver	Temperature	CO ₂ absorbed per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surf.	CO ₂ absorbed corr. for temperature and CO ₂ content	Intensity of light (Bunsen's units)	Size of stomatal openings
1	9/9 16	48.0	32	0.54	0.45	16°	0.7	1.1	4.5	
2	»	48.0	31	0.54	0.51	16°	0.2	0.3	0.8	
3	»	48.0	30	0.54	0.44	16°	0.8	1.3	4.5	
4	»	48.0	30	0.54	0.54	16°	0	0	0	

Table VIII. *Ajuga reptans*.

Nr.	Date	Area of leaf in square centimeters (upper + lower surface)	Rate of air current in minutes for 1 l	CO ₂ in air in mg per l	Mean CO ₂ content of air in the receiver	Temperature	CO ₂ absorbed per hour per 50 cm ² of the upper surf. + 50 cm ² of the lower surf.	CO ₂ absorbed corr. for temperature and CO ₂ content	Intensity of light (Bunsen's units)	Size of stomatal openings
1	28/7 13	100.0	35	0.62	0.47	20°	0.5	0.6	9.0	
2	»	100.0	32	0.62	0.50	20°	0.5	0.6	1.8	
3	»	100.0	31	0.62	0.55	21°	0.3	0.3	0.2	
4	»	100.0	32	0.62	0.67	21°	÷ 0.2	÷ 0.2	0	
5	2/8 14	38.0	29	0.64	0.56	24°	0.9	0.7	14.0	
6	»	38.0	29	0.64	0.59	24°	0.5	0.4	1.0	
7	»	38.0	29	0.64	0.64	24°	0	0	0	
8	3/8 14	64.0	29	0.65	0.52	22°	0.8	0.7	6.6	1
9	»	64.0	29	0.65	0.61	23°	0.3	0.2	0.2	1
10	»	64.0	29	0.65	0.69	23°	÷ 0.3	÷ 0.3	0	1

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Studier over Stofproduktionen hos Lys- og Skyggeplanter.

(Resumé).

Af

P. Boysen Jensen.

Hensigten med de foreliggende Undersøgelser har været at foretage en Sammenligning mellem Lys- og Skyggeplanter med Hensyn til Ernæringsvirksomhedens Økonomi. Stofproduktionen (Tilvæksten i Tørstof) i et bestemt Tidsrum vil fremkomme som en Differens mellem en Indtægt, der hovedsagelig indvindes gennem Assimilationen af Luftens Kulsyre, og en Udgift, der skyldes Stoftabet gennem Aandedræt, Tab af Blade, Produktion af Frø etc. For at sammenligne Stofproduktionen hos forskellige Planter vil det være hensigtsmæssigt at udtrykke den i Procent af den Tørstofmængde, Planten indeholder. Hvis saaledes en Plante med et Indhold af 100 g Tørstof i Løbet af et Døgn forøger sin Tørstofmængde med 20 g, er den procentiske Tørstofproduktion pr. Dag 20.

For at bestemme denne Størrelse maa man først bestemme Plantens Bladareal i Forhold til Tørstofindholdet af Blade, Stængel og Rod. Tørstofindholdet beregnes paa et Bladareal af 50 cm^2 (kun den ene Side af Bladet maales).

Dernæst maa man bestemme Kulsyreassimilationens Intensitet i forskellige Lysstyrker pr. 50 cm^2 Bladareal. Dette sker ved Hjælp af det i Fig. 1 afbildede Apparat. Princippet i dette Apparat er, at der suges en Strøm af atmosfærisk Luft hen over Bladet; man absorberer og bestemmer den Kulsyremængde, som ikke er optaget af Bladet, og kan da, naar man tillige bestemmer Luftens Kulsyreindhold, beregne, hvor meget Kulsyre Bladet har optaget. Luftstrømmen frembringes ved, at Flaskerne *A* og *B* anbringes i forskellig Højde. Hvis *A* er fyldt med Vand, og *B* bliver anbragt nederst, vil Vandet strømme fra *A* til *B*, og samtidig vil der suges Luft ind i *A* gennem Slangen *a*. Mængden af den gennemsugede Luft kan maales ved én paa Flaskerne anbragt Inddeling. Luften kan, naar Flaskerne byttes om, bringes til at vedblive at strømme i den samme Retning ved en Drejning af Hanerne i Apparatet *C*. Luften passerer først Bladet, der er anbragt i Reci-

pienten *E* og gaar dernæst gennem Absorbtiionsapparatet *D*. Kulsyren absorberes ved Hjælp af Barytvand og Mængden af Kulsyre bestemmes ved Titring med Saltsyre.

Respirationen kan maales ved Hjælp af det samme Apparat.

Lysstyrken bestemmes ved Hjælp af fotografisk Papir, der er sensibiliseret med Rhodamin B' (ANDRESEN, 1898), saaledes at det ogsaa er følsomt for de røde Straaler. Det lysfølsomme Papir anbringes i et Lysmaalingsapparat (Fig. 2). For at bestemme Lysstyrken maaler man, hvor lang Tid det varer, inden Papiret antager en bestemt Farvetone. Denne Tid er omvendt proportional med Lysstyrken.

Naar man da har bestemt den daglige Variation i Lysstyrken f. Eks. i Juli Maaned og man tillige har bestemt Kulsyreassimilationens Styrke hos en bestemt Plante ved forskellige Lysstyrker samt Respirationen, kan man beregne den daglige procentiske Tørstofproduktion. Denne kan imidlertid ogsaa bestemmes direkte. Hvis nemlig Tørstofproduktionen vokser proportionalt med Plantens Masse, hvad der tilnærmelsesvis vil være Tilfældet hos unge Planter, hos hvilke en bestemt Del af det nydannede organiske Stof medgaar til Dannelsen af nye Blade, kan den daglige Tørstofproduktion (x) beregnes efter Ligningen $a(1+x)^n = b$, naar a er Plantens Tørstofindhold ved Begyndelsen, b dens Tørstofindhold ved Slutningen af Forsøget og n Forsøgets Varighed i Dage.

Stofproduktionen hos Lysplanter. Forsøgene blev anstillet med *Sinapis alba*, *Senecio silvaticus*, *Rumex acetosella* og *Sambucus nigra*. Kulsyreassimilationens Afhængighed af Lysstyrken hos disse Planter er gengivet i Fig. 3 og 4 p. 238—39. Man ser, at Kurverne begynder under Abscisseaksen; ved Lysstyrken 0 finder der nemlig en Kulsyreudvikling Sted som Følge af Bladenes Aandedræt. Ved den Lysstyrke, hvor Kurven skærer Abscisseaksen, holder Aandedræt og Kulsyreassimilation hinanden i Ligevægt. Kurven stiger i den første Del omtrent proportionalt med Lysstyrken, dernæst bøjer den om og bliver til sidst parallel med Abscisseaksen.

For de undersøgte Lysplanter er Respirationen 0.3—0.8 mg og den maximale Kulsyreassimilation 2.3—6.0 mg pr. Time pr. 50 cm² (20°). Den Lysstyrke, ved hvilken Respiration og Kulsyreassimilation holder hinanden i Ligevægt, er 0.7—1.0 (o: ca. $\frac{1}{10}$ af Lysstyrken paa en Solskinsdag om Sommeren midt paa Dagen).

Ved Hjælp af disse Maalinger og den pag. 234 anførte Tabel

over Variationen i den daglige Lysstyrke i Juli Maaned har jeg forsøgt at beregne Tørstofproduktionen hos unge Planter af *Sinapis*. Beregningerne er anført pag. 243—44. Resultatet af disse Beregninger er, at den procentiske Tørstofproduktion pr. Døgn i Juli Maaned kan anslaaes til 16.5, med andre Ord, at en ung *Sinapis*plante i Løbet af et Døgn forøger sin Tørstofmængde med 16.5 %.

Dette Tal stemmer temmelig godt med direkte Bestemmelser. Dels har jeg selv bestemt Tørstofproduktionen ved Kultur af *Sinapis*-kimplanter i Urtepotter og Bestemmelse af Tørstofvægten efter en vis Tids Forløb. Resultatet af disse Bestemmelser, der er udført til forskellige Aarstider, er gengivet i Figur 5 pag. 244. Endvidere har jeg beregnet Tørstofproduktionen ved Hjælp af Undersøgelser, der er anstillet af HORNBERGER (1885 p. 415). Resultatet af disse Beregninger er, at den procentiske Tørstofproduktion hos *Sinapis* pr. Døgn i Juli Maaned kan anslaaes til 13—17 %.

Stofproduktionen hos Skyggeplanter. Forsøgene blev anstillet med *Oxalis acetosella*, *Ajuga reptans*, *Senecio silvaticus* (Skyggeplante) og *Sambucus nigra* (Skyggeblade). Resultatet af Forsøgene over Kulsyreassimilationens Afhængighed af Lysstyrken er gengivet i Figur 7 pag. 248. En Sammenligning med de tilsvarende Kurver for Lysplanterne viser, at Bladene af Skyggeplanterne har et meget svagt Aandedræt, nemlig kun 0.1—0.2 mg CO₂ pr. Time pr. 50 cm². Den maximale Kulsyreassimilation er ogsaa ringe, ca. 0.8 mg CO₂ pr. 50 cm². Til Gengæld er Skyggeplanterne i Stand til at faa et positivt Udbytte af Kulsyreassimilationen i noget svagere Lys end Lysplanterne. Allerede ved en Lysstyrke af 0.2 er der Ligevægt mellem Kulsyreassimilation og Aandedræt. Den procentiske Tørstofproduktion vil hos mange Skyggepltr., selv om de vokser under gode Lysforhold, være ringe. Hos *Oxalis* er den daglige Tørstofproduktion i Juli Maaned beregnet til 2.1.

Mindre Meddelelser.

Ny Litteratur.

De danske Ælme-Arter.

I »Dansk Skovforenings Tidsskrift« 1918 har Professor C. H. Ostenfeld skrevet en Afhandling om vore Ælme-Arter. De karakteriseres hovedsagelig ved deres Blade, og der meddeles følgende Nøgle over dem:

A. Bladene bredest ovenfor Midten (omvendt ægformede), Bladstilken kort (1—5 mm).

a. Bladpladens Grund ikke stærkt skæv.

1. Bladets Overside tydeligt ru, Bladstilken stærkt haaret overalt: *Ulmus glabra* Huds. (= *U. montana* With.), Storbladet Ælm.

2. Bladets Overside glat og blank, Bladstilken næsten kun haaret paa Oversiden: *Ulmus glabra* Huds. var. *nitida* Fr.

b. Bladpladens Grund meget skæv, Bladets Overside glat, Bladstilken haaret, dog mest paa Oversiden: *Ulmus vegeta* (Loud.) C. K. Schm., Glatbladet Ælm.

B. Bladene bredest omtrent paa Midten (elliptiske), Oversiden glat, sjældnere svagt ru eller blødhåret, Bladstilken kort eller længere.

a. Bladenes Underside blødhåret, Bladgrunden meget skæv, Bladstilken kort (2—4 mm), overalt haaret; Bladets Sekundærnerver ikke tvegrenede mod Randen: *Ulmus laevis* Pall. (= *U. effusa* Willd.), Skærmblostmestret Ælm.

b. Bladenes Underside ru, Bladstilken længere (4—10 mm), oftest kun haaret paa Oversiden; nogle af Bladets Sekundærnerver tvegrenede mod Randen.

1. Bladene store, bredt elliptiske, med skæv Grund, Bladstilk ret kort: *Ulmus hollandica* Mill., Hollandsk Ælm.

2. Bladene middelstore, bredt elliptiske, med meget skæv Grund, Bladstilk ret lang: *Ulmus campestris* L., Smaabladet Ælm.

3. Bladene smaa, elliptiske eller lancetformet-elliptiske, med lidet skæv Grund: *Ulmus sativa* Mill. (= *U. suberosa* Fl. dan.), Engelsk Ælm.

U. glabra findes i hele Landet undtagen Vestjylland; dens Varietet *nitida* er kun funden paa Bornholm og Viksø (N. for Lolland). *U. vegeta*,

som skal være en Hybrid, kendes kun fra Birkerød, Dronninggaard og Skodsborg. *U. laevis* plantes hist og her i Parker og som Allétræ, og det samme gælder *U. hollandica*, der ogsaa skal være en Hybrid. *U. campestris* er en mangeformet Art med vid Udbredelse i det tempererede Europa og Asien; her i Landet ses den kun plantet og er kun kendt fra Øerne. Til *U. sativa* hører vor Kork-Ælm som næppe er oprindelig vildtvoksende her; den er kendt fra Sjælland og fra Syd-Jylland.

I Afhandlingen findes Billeder af Bladformer og et Kort over *U. glabra*'s Udbredelse i Danmark.

Forfatteren udtaler, at det var ønskeligt at faa flere Oplysninger om vore Ælme-Arters Udbredelse i Landet, og haaber, at hans Redegørelse for dem kan bidrage dertil. O. P.

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Personalialia.

Dr. phil. Ove V. Paulsen er blevet udnævnt til Inspektør ved Universitetets botaniske Museum fra 1. Maj 1918 at regne.

Museumsamanuensis, Mag. sc. Carl Christensen er blevet udnævnt til Amanuensis ved Universitetets botaniske Have fra 1. Maj 1918.

Mag. sc. Johs. Grøntved er blevet udnævnt til Amanuensis ved Universitetets botaniske Museum fra 1. Maj 1918.

Cand. pharm. Fr. Mathiesen absolverede Magisterkonferens i Naturhistorie med Botanik som Hovedfag i Juni 1918.

Universitetets Guldmedaille er blevet tildelt Mag. sc. Carsten Olsen for hans Besvarelse af den i 1915 udsatte Prisopgave om en morfologisk, biologisk og formationsstatistisk Undersøgelse af Mosserne og Karplanterne i de danske Egeskovs og Egekrats Bundflora.

Professor, Dr. W. Johannsen, er blevet udnævnt til Æresdoktor i Medicin ved Lunds Universitet i Anledning af dettes 25-Aars Jubilæum den 27. September 1918.

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